

National Aeronautics and Space Administration



Division Update to AFTA Science Definition Team

April 1, 2014

Astrophysics

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www.nasa.gov

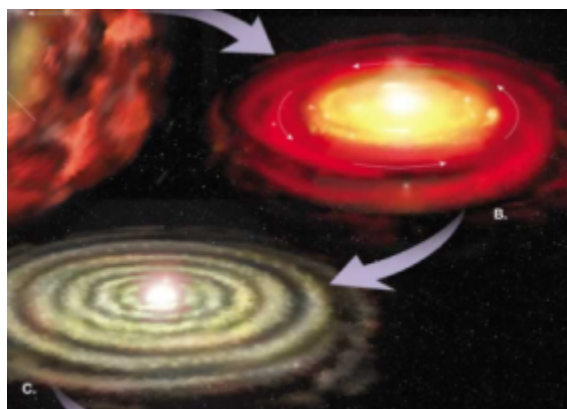


Why Astrophysics?

Astrophysics is humankind's scientific endeavor to understand the universe and our place in it.



1. How did our universe begin and evolve?

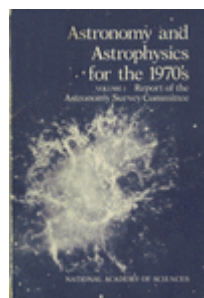


2. How did galaxies, stars, and planets come to be?

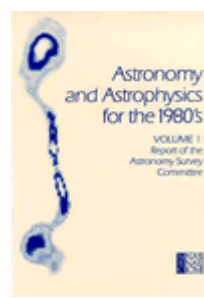


3. Are We Alone?

These national strategic drivers are enduring



1972



1982



1991



2001



2010

ASTROPHYSICS

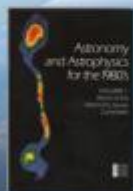
Decadal Survey Missions

1990



1972
Decadal
Survey
Hubble

1999



1982
Decadal
Survey
Chandra

2003



1991
Decadal
Survey
Spitzer

LRD: 2018



2001
Decadal
Survey
JWST

LRD: 2020s



2010
Decadal
Survey
WFIRST



The Big Picture

- This remains a time of scientific opportunity for NASA Astrophysics.
 - We are poised to answer the most compelling science questions.
 - The budget for NASA astrophysics, which includes JWST, continues at \$1.33B in FY14; the President has requested \$1.25B in FY15.
 - NASA continues to operate large and small space-based observatories spanning the electromagnetic spectrum, including multiple Great Observatories.
 - The James Webb Space Telescope, the highest priority of the community, is on schedule and fully funded for an October 2018 launch.
 - NASA continues to develop Explorer missions and contributions to international missions for launch this decade, and a Small Explorer AO is planned for late 2014 to select two more Explorer projects.
 - NASA continues to support individual investigators for data analysis, theory, and technology investigations through open, competitive, peer reviews.
 - NASA is preparing for a new strategic Astrophysics mission to follow JWST as soon as funding becomes available; the President has requested FY15 funding for preformulation studies of WFIRST/AFTA.
- The budgetary future remains uncertain.
 - Priorities must be used to guide difficult budget choices.
 - The President has requested a ~10% decrease for the Astrophysics Division in FY15; the cost of operating SOFIA can not be accommodated within this reduced budget.



Progress Toward Decadal Survey Priorities

The NASA FY14 Appropriation, the President's FY15 Budget Request, and its notional out years support

L1. WFIRST	Preformulation and focused technology development for WFIRST/AFTA (a 2.4m version of WFIRST with a coronagraph) are underway to enable a new start NET FY17
L2. Augmentation to Explorer Program	Increased from ~\$90M in FY07 and ~\$115M/yr in FY10 to ~\$140M/yr in FY16 and beyond; supports decadal cadence of AOs including 2014
L3. LISA	Strategic technology investments including LISA Pathfinder plus discussing partnership in ESA's L3 gravitational wave observatory
L4. IXO	Strategic technology investments plus discussing partnership in ESA's L2 X-ray observatory
M1. New Worlds Technology Development Program	Focused technology development for a coronagraph on WFIRST; mission concept studies and strategic technology investments
M2. Inflation Probe Technology Development Program	Three balloon-borne investigations plus strategic technology investments
Small. Research Program Augmentations	Increased from \$65M (FY07) to \$74M (FY10) to \$82M (FY12 and beyond)



Astrophysics Budget Strategy

- Use the scientific priorities of the 2010 Decadal Survey to guide strategy and inform choices.
- There is inadequate available budget to implement the 2010 Decadal Survey recommendations as written.
- A goal is to be prepared to start a new strategic NASA Astrophysics mission to follow JWST as soon as funding becomes available, while continuing to advance Decadal Survey science during the interim.
 - WFIRST/AFTA (WFIRST using existing 2.4 m telescopes including coronagraph)
 - Moderate missions (“probes”) derived from the science objectives of the prioritized missions and recommendations in the 2010 Decadal Survey are being studied, in addition to a large mission (WFIRST), to be prepared for a mid-decade decision.
- As appropriate, collaborate with international partners to realize Decadal Survey priorities and recommendations.
 - Partner on ESA’s Euclid mission (complements WFIRST commitment)
 - Partner on ESA’s L2 x-ray observatory (responds to IXO recommendation)
 - Partner on ESA’s L3 gravitational wave observatory (responds to LISA recommendation)



FY14 Budget Appropriation

- FY14 President's budget requested \$642M for Astrophysics and \$658M for JWST.
 - Request includes full funding required for JWST; new projects for TESS, NICER, Euclid; mission extensions per 2012 Senior Review; core funding for research and suborbital projects; planning budget wedge for strategic mission starting in FY17.
 - Request includes no funding for education.
- Final FY14 Appropriation is \$668M for Astrophysics and \$658M for JWST.
 - JWST plan for 2018 launch is fully funded.
 - Budget is \$26M higher for Astrophysics than requested, including \$56M directed funding for WFIRST/AFTA studies (compared with \$13M planned).
 - Remainder of Astrophysics (other than JWST and WFIRST/AFTA) must be adjusted to accommodate the ~\$20M difference. This will be determined through development of the NASA FY14 operating plan.
 - SMD to continue conducting education activities in FY14 and to consider consolidation at the Division level.
- FY15 President's budget request was released on March 4 (top level only) and March 10 (full details)

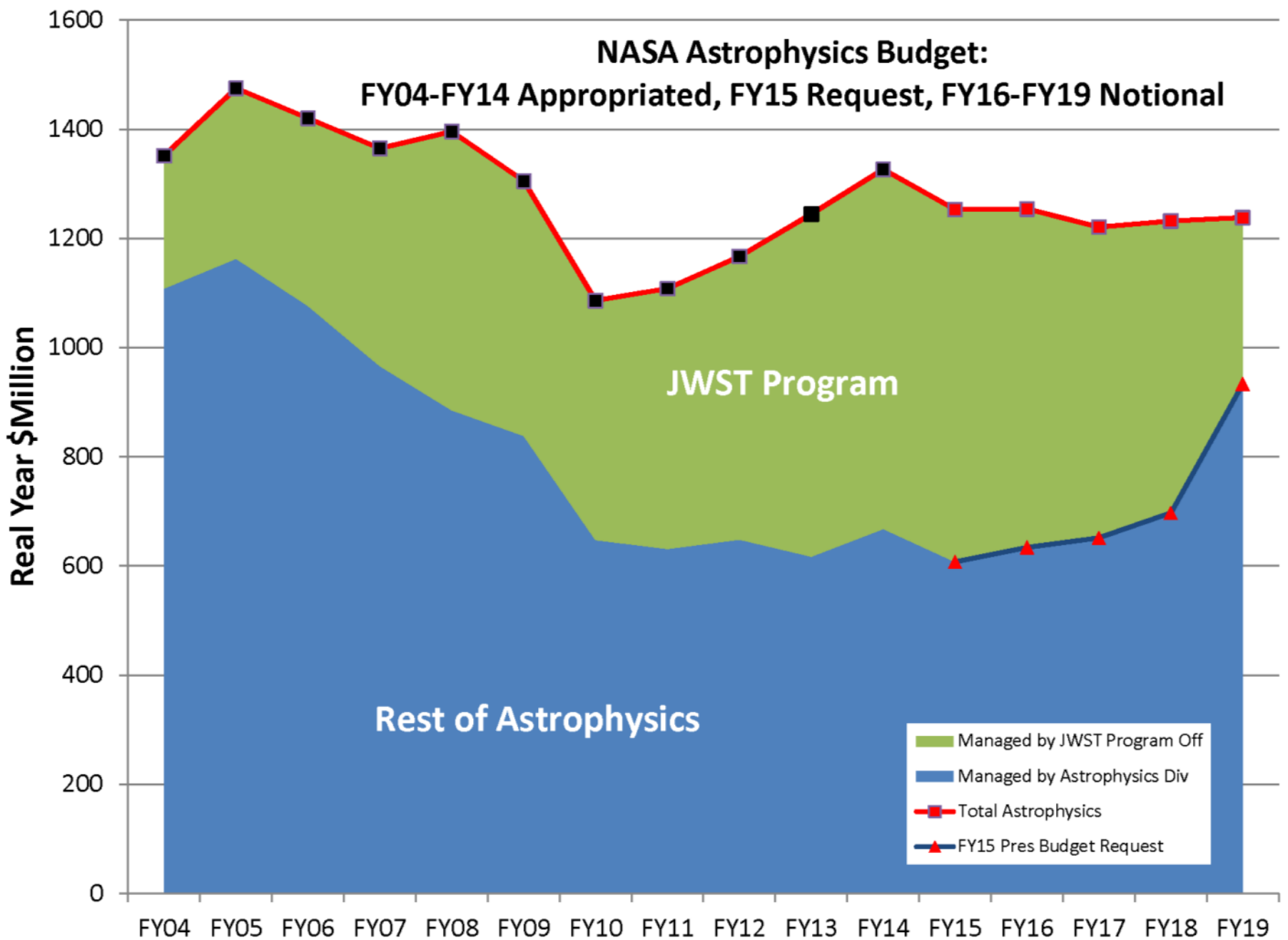


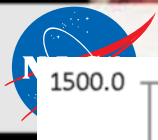
Astrophysics

Outyears are notional

(\$M)	2013	2014	2015	2016	2017	2018	2019
Astrophysics	\$617	\$668	\$607	\$634	\$651	\$697	\$993
JWST	\$627	\$658	\$645	\$620	\$569	\$535	\$305

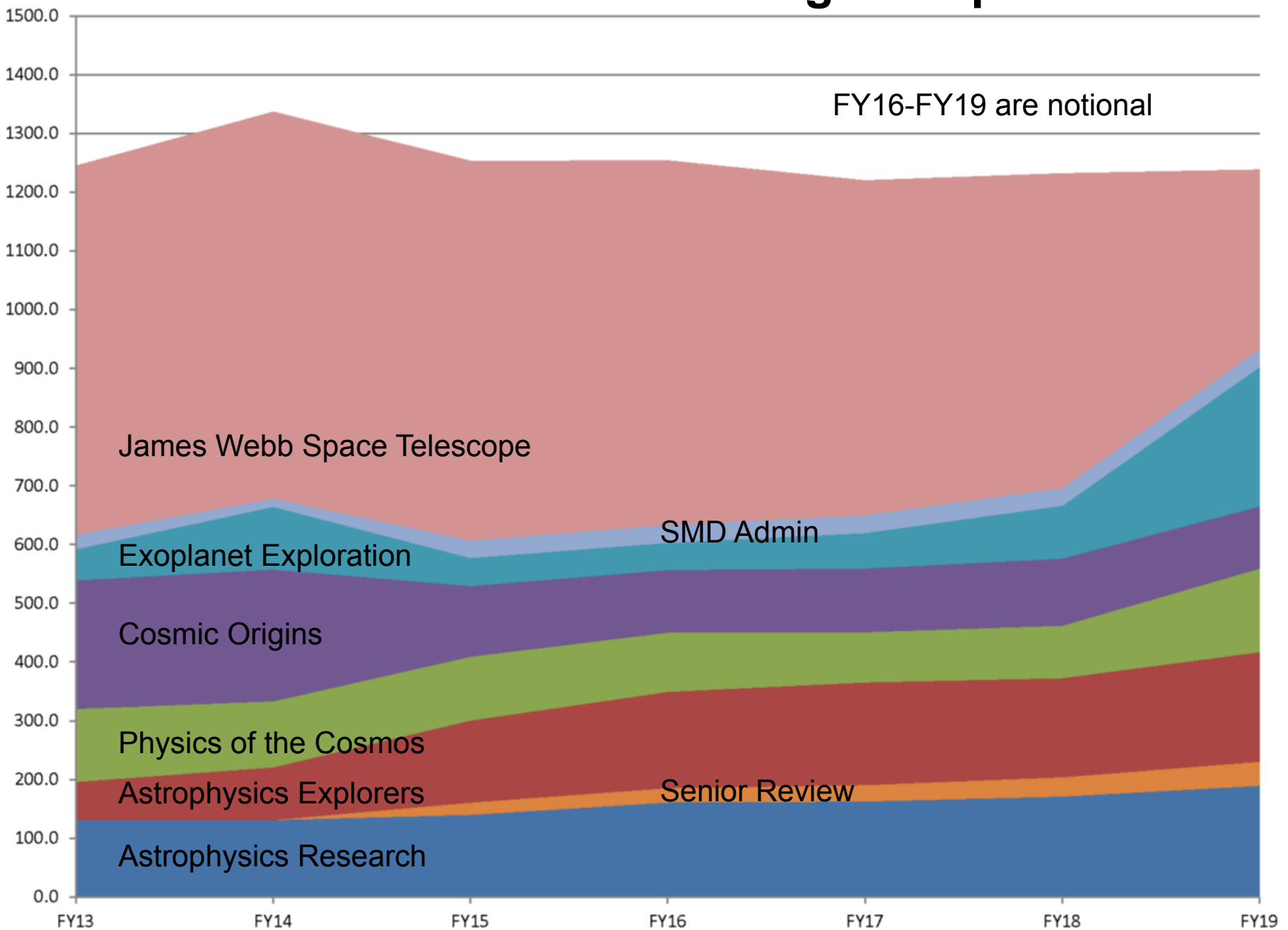
- Supports pre-formulation of WFIRST/AFTA, including technology development for detectors and coronagraph.
- Supports a growing Astrophysics Explorer program with continued development of ASTRO-H, NICER, and TESS, and initiation of the next Small Explorer mission.
- Supports operating missions: Hubble, Chandra, and other missions rated highly by the 2014 Senior Review.
- Continues a competed astrophysics research program and support of the balloon program.
- Seeks to work with current partner Germany and potential partners to identify a path forward for SOFIA with greatly reduced NASA funding. Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.
- Supports the commitment to an October 2018 launch date for JWST. Continues manufacturing of the flight sunshield structure and membranes. Completes and delivers the flight cryogenic cooler tower assembly. Delivers the Optical Telescope Element flight structure. Initiates integration of the 18 flight primary mirror segments. Conducts the final Integrated Science Instrument Module level cryo-vacuum test.





President's FY15 Budget Request

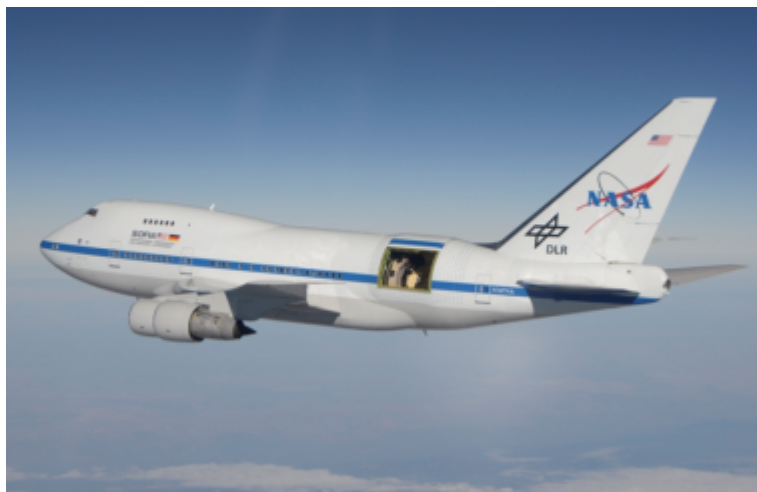
FY16-FY19 are notional





SOFIA

Stratospheric Observatory for Infrared Astronomy



- **World's Largest Airborne Observatory**
- 2.5-meter telescope
- Capable of observing from the visible to the far infrared
- 80/20 Partnership between NASA and the German Aerospace Center (DLR)
- Mission Ops based at NASA-Armstrong
- Science Ops based at NASA-Ames
- Six First-Generation instruments
 - Four U.S., two German
 - Imaging, Spectroscopy, and Photometry
- Limited Science Ops began 2010
- Full Operational Capability in February 2014

CURRENT STATUS:

- Completed 45 successful flights during Cycle 1
 - 25 science (153 research hours)
 - 9 instrument commissioning
 - 11 engineering/test and ferry for deployment
- Completed Inaugural Southern Hemisphere Deployment, July 2013, Christchurch NZ
 - 9 science flights in 14 nights
 - 100% of objectives achieved
- Completed all technical requirements for Full Operational Capability (FOC) in February 2014
 - FOC will be confirmed following independent review of FLITECAM commissioning data
 - EXES & FIFI-LS begin commissioning in 2014
- Cycle 2 science investigations chosen
 - Initiated February 2014
- Second generation instruments under development (1 U.S., 1 German)
 - HAWC+: far infrared imager and polarimeter
 - upGREAT: multi-pixel heterodyne spectrometer
- President's FY15 budget request proposes to end funding and place SOFIA in storage
 - NASA-DLR working group established to determine path forward



SOFIA to be put into Storage

- SOFIA's high operating costs cannot be accommodated within the reduced Astrophysics budget request.
- NASA's FY 2015 budget request to Congress proposes to place SOFIA into storage by FY 2015.
- NASA has informed our German partner DLR of this proposal. NASA is working with DLR to identify a path forward for SOFIA.



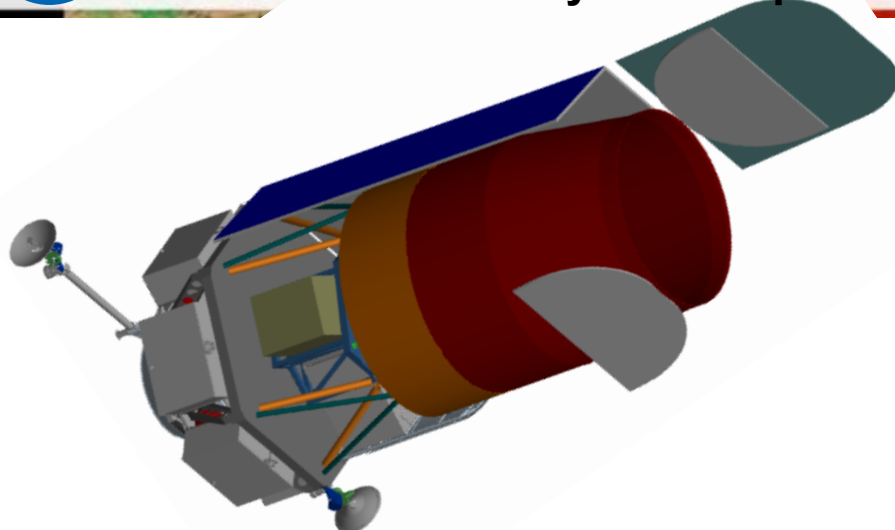
SOFIA Working Group

- NASA and DLR have formed a working group to develop a go forward plan for SOFIA. The WG is to conduct analysis under the following primary assumptions:
 - That the FY2015 budget request will be enacted without further change;
 - That the DLR contribution to SOFIA will not be increased;
 - That DLR does not desire to take over primary program management responsibility for SOFIA;
 - That transition of the Program Office from Armstrong Flight Research Center to Ames Research Center will not occur if the FY2015 budget request is enacted;
 - That, in the absence of additional partnerships, the deadline for SOFIA to enter storage is the end of FY2015, i.e. funding (not the calendar) drives entry into storage; and
 - That any plan must be consistent with available NASA FY2015 funding.
- Overall objectives will include maximizing scientific return within U.S. budget constraints; supporting critical near-term decisions; and identification of long-term options for continued operations or for storage until such time that additional funds are made available for resumption of SOFIA operations.
 - April 4 - Presentation of Findings on Near Term Items
 - April 25 - Final Presentation of Findings on SOFIA Transition Options



WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets



CURRENT STATUS:

- **Top priority in 2010 Decadal Survey**
 - #1 Large Priority: Widefield IR survey telescope
 - #1 Medium Priority: Technology for direct imaging and characterization of exoplanets
 - **Study Baseline Payload:**
 - 2.4m existing telescope assets
 - Widefield imager
 - Coronagraph
 - **Science objectives:**
 - Determine the history of cosmic expansion and growth of structure
 - Complete statistical census of planetary systems
 - Produce deep sky map at NIR wavelengths
 - Directly image giant planets and debris disks
 - General observer program
- May 2013, NASA Administrator Bolden directed study of WFIRST/AFTA and preserve option for FY17 new start if budget is available
 - No decision expected before early 2016
 - Currently in pre-formulation phase
 - AFTA endorsed by NRC study report released March 2014.
 - SDT final report due Jan 2015
 - Maturing key technologies to TRL 5 by FY17 and TRL 6 by FY19
 - H4RG infrared detectors for widefield imager
 - Internal coronagraph for exoplanet characterization (two architectures identified December 2013; occulting mask coronagraph and phased induced amplitude apodization complex mask coronagraph)
 - FY14 Appropriation and FY15 Request support
 - Assessment of the 2.4m telescopes, mission design trades, payload accommodation studies, and observatory performance simulations



WFIRST/AFTA to continue Pre-Formulation

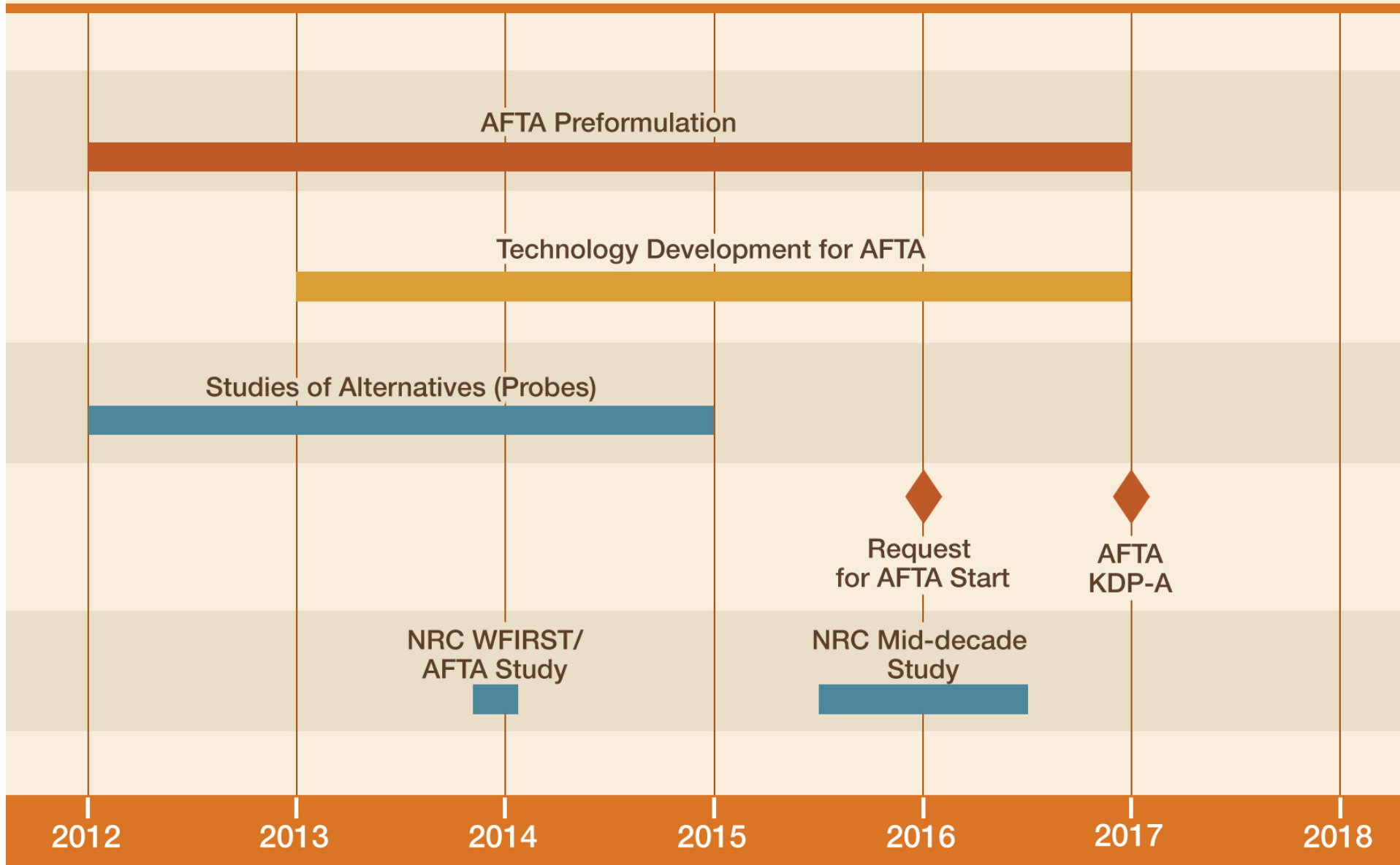
- Supports pre-formulation of WFIRST/AFTA, including technology development for detectors and coronagraph.
- Continues efforts from FY14 such as:
 - The WFIRST/AFTA Science Definition Team (SDT) report in early 2015 including a design reference mission and draft science requirements.
 - The WFIRST/AFTA Study Office including continued assessment of the 2.4m telescopes, mission design trades, payload accommodation studies, and observatory performance simulations.
 - Technology development for H4RG detectors for the wide field camera.
 - Technology development for the primary coronagraph architecture (occulting mask coronagraph) and the backup coronagraph architecture (phased induced amplitude apodization complex mask coronagraph).
- Supports Agency/Administration decision for formulation to begin NET FY 2017, should funding be available.



Plan for WFIRST-AFTA Preformulation

Widefield Infrared Survey Telescope using
Astrophysics Focused Telescope Assets

AFTA timeline



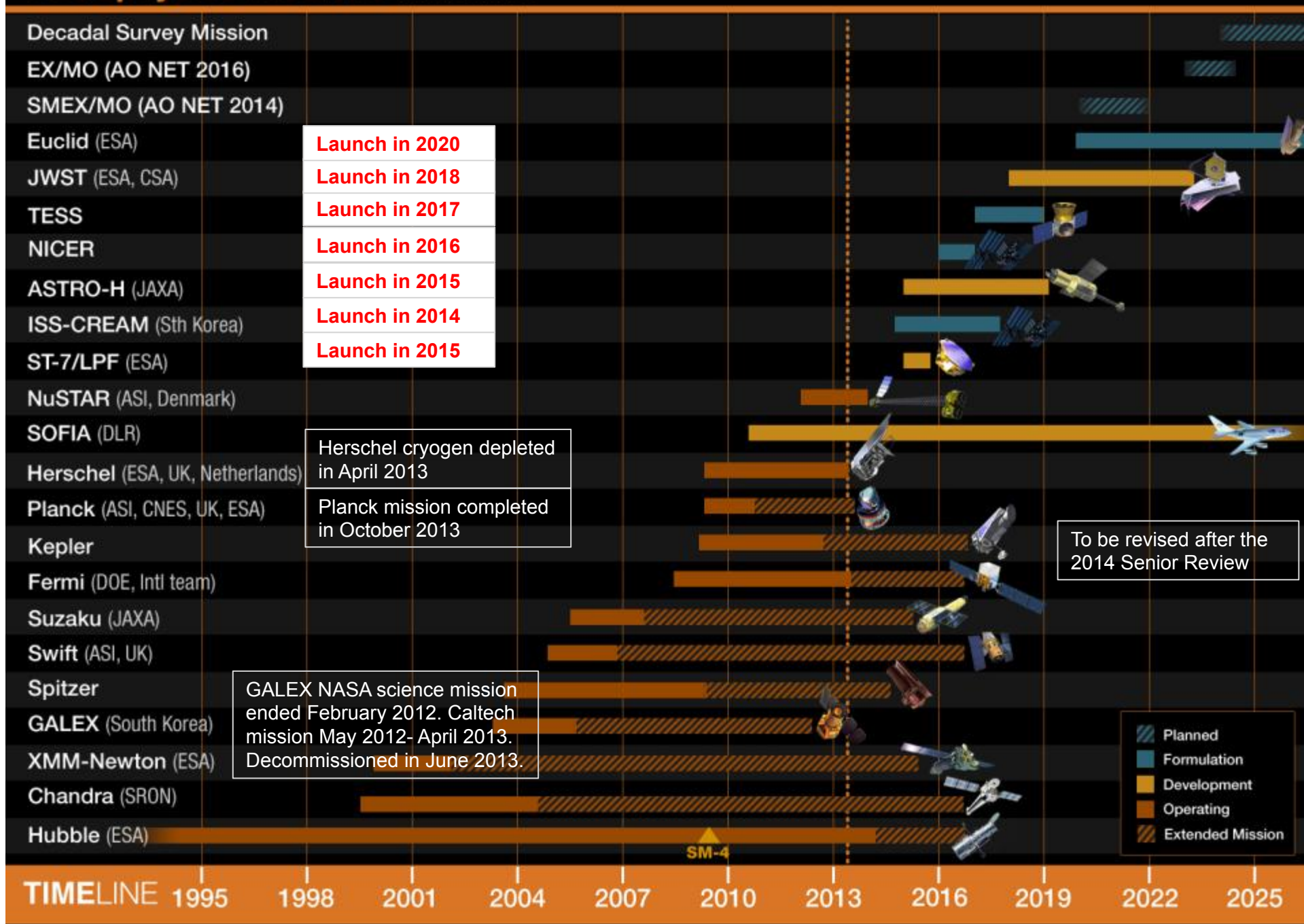


NRC study on WFIRST/AFTA

- NRC study on WFIRST/AFTA offers positive view of AFTA
 - (F3-2) AFTA significantly enhances WFIRST science in NWNH
 - (F1-7) Coronagraph satisfies some aspects of exoplanet technology
 - (F3-3) If AFTA costs compromise program balance, then it is inconsistent with rationale for #1 ranking
 - (F2-4) Risk of cost growth is significantly higher for AFTA than IDRM
 - (F2-6) Adding technology development to flagship creates risks
 - (F2-7) WFIRST's low risk was part of rationale; adding coronagraph compromises rationale
 - (F2-8) Adding coronagraph is not first tier priority for constrained budget; first tier priorities are: WFIRST, Explorers augmentation, core program augmentation; if higher priorities not addressed, adding coronagraph is inconsistent with NWNH priorities
 - (R2-1) Aggressively mature coronagraph design and plans; have independent review to determine whether to descope coronagraph
 - (R3-1) Have external technical and cost review of WFIRST/AFTA mission early enough to rescope mission to see if cost/risk consistent with NWNH



Astrophysics Missions timeline





Backup

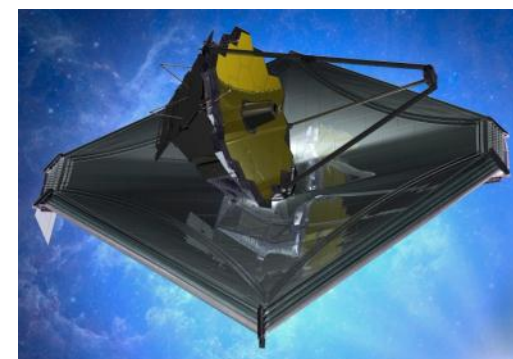
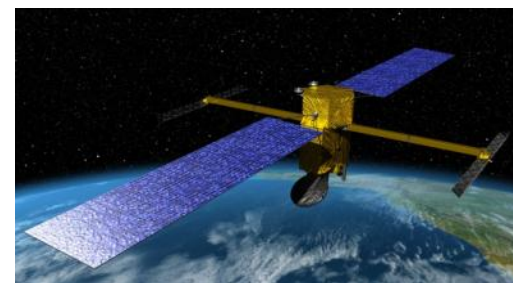


Science Mission Directorate

Outyears are notional

(\$M)	2013	2014	2015	2016	2017	2018	2019
Science	\$4,782	\$5,151	\$4,972	\$5,022	\$5,072	\$5,123	\$5,174

- Supports the 2018 launch of the James Webb Space Telescope and pre-formulation of WFIRST/AFTA, including technology development for detectors and coronagraph.
- Continues formulation and development of Solar Probe Plus, the InSight, Mars Rover 2020, and MOMA/ExoMars missions to Mars, and the development of the robotic OSIRIS-REx mission to retrieve and return samples from an asteroid, as well as pre-formulation work for a potential mission to Jupiter's moon, Europa.
- Develops and implements plans for measurements of solar irradiance, ozone profiles, and Earth radiation budget, and maintains weather and climate change modeling capabilities to enhance forecast accuracy.
- Proposes placing SOFIA into storage due to its high operating cost and budget constraints, but funds about 35 missions currently preparing for launch, and sustains nearly 60 operating missions.





Astrophysics FY 2015 Budget Request

Notional

	FY 2013 Op Plan	FY 2014 Op Plan	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Astrophysics	617.0	668.0	607.3	633.7	651.2	696.8	993.0
Astrophysics Research	155.8	134.9	191.0	216.2	221.2	234.6	261.2
Cosmic Origins	218.9	224.2	120.3	106.4	108.2	114.2	105.8
Physics of the Cosmos	124.5	112.6	108.8	100.9	86.6	89.4	142.4
Exoplanet Exploration	52.8	106.7	47.5	46.4	60.4	89.8	237.3
Astrophysics Explorers	65.1	89.6	139.7	163.7	174.9	168.7	186.4
James Webb Space Telescope	627.6	658.2	645.4	620.0	569.4	534.9	305.0
Astrophysics + JWST	1,244.6	1,326.2	1,252.7	1,253.7	1,220.6	1,231.7	1,298.0



FY 2015 Budget Request

	FY 2013 Op Plan*	FY 2014 Enacted**	FY2015	FY2016	FY2017	FY2018	FY2019
Science	4,781.6	5,151.2	4,972.0	5,021.7	5,071.9	5,122.6	5,173.9
Earth Science	1,659.2	1,826.0	1,770.3	1,815.5	1,837.6	1,861.9	1,886.3
Planetary Science	1,274.6	1,345.0	1,280.3	1,304.9	1,337.1	1,355.7	1,374.1
Astrophysics	617.0	668.0	607.3	633.7	651.2	696.8	993.0
James Webb Space Telescope	627.6	658.2	645.4	620.0	569.4	534.9	305.0
Heliophysics	603.2	654.0	668.9	647.6	676.6	673.3	675.5
Aeronautics	529.5	566.0	551.1	556.6	562.2	567.8	573.5
Space Technology	614.5	576.0	705.5	712.6	719.7	726.9	734.2
Exploration	3,705.5	4,113.2	3,976.0	4,079.9	4,061.2	4,119.5	3,673.4
Exploration Systems Development	2,883.8	3,115.2	2,784.4	2,863.3	2,917.7	2,993.9	3,106.6
Commercial Spaceflight	525.0	696.0	848.3	872.3	791.7	730.9	172.0
Exploration Research and Development	296.7	302.0	343.4	344.3	351.8	394.7	394.7
Space Operations	3,724.9	3,778.0	3,905.4	3,951.9	4,051.0	4,073.8	4,601.8
Space Shuttle	38.8		0.0	0.0	0.0	0.0	0.0
International Space Station	2,775.9		3,050.8	3,126.5	3,266.9	3,290.3	3,818.6
Space and Flight Support (SFS)	910.2		854.6	825.4	784.1	783.5	783.2
Education	116.3	116.6	88.9	89.8	90.7	91.6	92.6
Cross Agency Support	2,711.0	2,793.0	2,778.6	2,806.4	2,834.4	2,862.8	2,891.4
Center Management and Operations	1,991.6		2,038.8	2,059.2	2,079.7	2,100.5	2,121.6
Agency Management and Operations	719.4		739.8	747.2	754.7	762.3	769.8
Construction & Envrmtl Compl Restoration	646.6	515.0	446.1	379.0	382.7	386.6	390.4
Construction of Facilities	589.5		370.6	302.7	305.7	308.7	311.8
Environmental Compliance and Restoration	57.0		75.5	76.3	77.0	77.8	78.6
Inspector General	35.3	37.5	37.0	37.4	37.7	38.1	38.5
Grand Total	16,865.2	17,646.5	17,460.6	17,635.3	17,811.5	17,989.7	18,169.7

**FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1); it also includes sequester per BBEDCA Section 215A, and August 2013 Operating Plan.*

***FY 2014 reflects funding levels provided in P.L. 113-76, Consolidated Appropriations Act, 2014.*

Note: Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.



Astrophysics Program Content

	Op Plan Enacted		FY15	Notional			
	FY13	FY14		FY16	FY17	FY18	FY19
Astrophysics	617.0	668.0	607.3	633.7	651.2	696.8	933.0
<u>Astrophysics Research</u>	<u>155.8</u>		<u>191.0</u>	<u>216.2</u>	<u>221.2</u>	<u>234.6</u>	<u>261.2</u>
Astrophysics Research and Analysis	65.0		66.0	70.2	71.5	71.5	71.5
Balloon Project	33.0	32.9	38.3	34.2	34.3	37.3	37.4
<u>Other Missions and Data Analysis</u>	<u>57.8</u>		<u>86.6</u>	<u>111.8</u>	<u>115.3</u>	<u>125.8</u>	<u>152.2</u>
Astrophysics Data Program	16.9		17.0	17.6	17.6	17.6	17.6
Astrophysics Data Curation and Archival	16.0		18.6	19.1	19.1	19.1	19.1
Astrophysics Senior Review			21.0	24.4	28.0	32.9	41.0
Education and Public Outreach	10.1		15.0	15.0	15.0	15.0	15.0
Contract Administration, Audit & QA Svcs	14.7		15.0	15.5	15.5	15.5	15.5
Astrophysics Directed R&T				20.3	20.1	25.8	44.1
<u>Cosmic Origins</u>	<u>218.9</u>		<u>120.3</u>	<u>106.4</u>	<u>108.2</u>	<u>114.2</u>	<u>105.8</u>
Hubble Space Telescope (HST)	93.3	98.3	75.3	91.8	88.2	92.3	83.9
SOFIA	77.5		12.3				
<u>Other Missions and Data Analysis</u>	<u>48.1</u>		<u>32.7</u>	<u>14.6</u>	<u>20.0</u>	<u>21.9</u>	<u>21.9</u>
SIRTF/Spitzer	15.3		14.2				
Herschel	21.1		5.5	2.7	1.0		
Cosmic Origins SR&T	8.6		8.8	8.2	15.2	17.0	17.0
Cosmic Origins Future Missions	0.3		1.6	1.0	1.0	2.0	2.0
Cosmic Origins Program Management	2.7		2.6	2.7	2.8	2.9	2.9



Astrophysics Program Content (cont'd)

	Op Plan	Enacted	Notional				
	FY13	FY14	FY15	FY16	FY17	FY18	FY19
<u>Physics of the Cosmos</u>	<u>124.5</u>		<u>108.8</u>	<u>100.9</u>	<u>86.6</u>	<u>89.4</u>	<u>142.4</u>
Euclid	13.8		15.0	7.3	5.9	5.9	6.0
Chandra X-Ray Observatory	57.3		55.8	55.4	55.6	55.6	55.6
Fermi Gamma-ray Space Telescope	24.9		18.6	18.6			
Planck	7.3		4.1				
XMM	1.9		1.0				
Physics of the Cosmos SR&T	15.9		10.6	15.8	21.1	22.8	34.7
Physics of the Cosmos Program Mgmt	2.9		2.8	2.8	2.9	3.0	3.0
Physics of the Cosmos Future Missions	0.4		1.0	1.0	1.1	2.1	43.0
 <u>Exoplanet Exploration</u>	 <u>52.8</u>		 <u>47.5</u>	 <u>46.4</u>	 <u>60.4</u>	 <u>89.8</u>	 <u>237.3</u>
Kepler	19.1						
Keck Operations	5.7		6.0	6.1	6.1	6.2	6.2
Large Binocular Telescope Interferometer	2.6		2.0	1.1	1.3		
Astrophysics Decadal Strategic Mission		56.0	14.0	14.0	21.1	51.4	198.0
Exoplanet Exploration SR&T	20.5		17.8	18.2	24.9	25.1	25.2
Exoplanet Exploration Program Mgmt	4.2		5.8	5.8	5.8	6.0	5.9
Exoplanet Exploration Future Missions	0.7		2.0	1.2	1.1	1.0	2.0



Astrophysics Program Content (cont'd)

	Op Plan	Enacted	Notional				
	FY13	FY14	FY15	FY16	FY17	FY18	FY19
<u>Astrophysics Explorer</u>	<u>65.1</u>		<u>139.7</u>	<u>163.7</u>	<u>174.9</u>	<u>168.7</u>	<u>186.4</u>
Transiting Exoplanet Survey Satellite (TESS)	34.8		98.8	100.8	102.7	13.9	9.1
<u>Other Missions and Data Analysis</u>	<u>30.3</u>		<u>40.9</u>	<u>63.0</u>	<u>72.2</u>	<u>154.7</u>	<u>177.2</u>
Neutron Star Interior Composition Explorer	6.4		11.1	11.6	3.6	1.4	
Astro-H (SXS)	8.9		14.4	11.0	12.0	11.4	9.5
SWIFT	4.9		5.0	5.1			
Suzaku (ASTRO-E II)	0.3		0.3				
Nuclear Spectroscopic Telescope Array	1.9		0.4				
Gravity and Extreme Magnetism	2.0						
Wide-Field Infrared Survey Explorer	0.6						
Astrophysics Explorer Future Missions	0.6		5.6	28.0	49.1	134.9	163.3
Astrophysics Explorer Program Mgmt	4.8		4.0	7.2	7.6	7.1	4.4
James Webb Space Telescope	627.6	658.2	645.4	620.0	569.4	534.9	305.0
Astrophysics/JWST Total	1244.6	1326.2	1252.6	1253.7	1220.6	1231.7	1238.0